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[Management Brief]

Unique Allacustrine Migration Patterns of a Bull Trout Population in the Pend Oreille River Drainage, Idaho

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Abstract.—We captured and radio-tagged six adult bull trout *Salvelinus confluentus* in a spawning tributary of the East River basin, Idaho. These fish were tracked for a year to determine the type of migration they endured to reach their overwintering and spawning locations. Our tracking efforts revealed that the fish made complex postspawning migrations downstream and then upstream either towards or into Lake Pend Oreille. To reach the lake, bull trout migrated at least 12 km out of the East River basin into the Priest River, traveled 34 km down the Priest River into the Pend Oreille River, and then turned upstream and migrated 36 km to Lake Pend Oreille. Three of the six bull trout returned to the East River basin during the subsequent spring. These movement patterns are uniquely complex and extensive for outlet-spawning or allacustrine bull trout. This work illustrates the type of allacustrine migrations bull trout can have and suggests the need for new approaches for accomplishing bull trout population expansion into historically occupied habitats. Eliminating barriers downstream of lakes could potentially contribute to and increase bull trout populations considerably.

Bull trout *Salvelinus confluentus* exhibit both resident and migratory life history strategies (Rieman and McIntyre 1993). Fluvial bull trout occupy smaller streams for their entire lives (Goetz 1989; Northcote 1997; Jakober et al. 1998). Migratory bull trout travel to spawn in streams that flow into lakes (lacustrine–adfluvial; Varley and Gresswell 1988; Northcote 1997) or that flow out of lakes (allacustrine), or they move from rivers into tributaries to spawn (fluvial–adfluvial). Juvenile fish rear in their natal streams for 1–4 years before returning to lakes or rivers to mature (Fraley and Shepard 1989; Goetz 1989; Northcote 1997; Swanberg 1997; Downs et al. 2006). Migratory forms of bull trout probably evolved because migration took them to places that increased their reproductive potential through a combination of increased survival, growth, and gamete production (Gross 1991). Fluvial forms of bull trout reside in predominantly cold and unproductive headwater tributaries that would not provide these same opportunities.

Spawning migrations of fluvial–adfluvial, lacustrine–adfluvial, and allacustrine forms of bull trout occur from lakes and rivers to tributaries where survival of eggs and young is optimized. In most cases, migratory bull trout, like most salmonids, move upstream into tributaries to spawn (USFWS 2002). Environmental cues from home streams guide fish migration back to spawning areas, and olfactory imprinting is probably the most significant guiding factor (Groves et al. 1968; Hara 1970; Hasler and Scholz 1983). Chemical cues originating in home waters are carried downstream past upstream-migrating fish and presumably guide them back to the spawning areas. However, optimal spawning and rearing habitat sometimes occurs in tributaries downstream of the lakes and rivers used by adults, thus necessitating downstream spawning migrations. Downstream migrations have been documented for spawning adults of rainbow trout *Oncorhynchus mykiss* from Loon Lake, British Columbia (Lindsey et al. 1959), and cutthroat trout *O. clarki* from Yellowstone Lake, Wyoming (Cope 1957). Brown and Mackay (1995) noted that fluvial and fluvial–adfluvial cutthroat trout within the Ram River drainage of Alberta also moved downstream to spawning areas, and Schmetterling (2001) noted this behavior in cutthroat trout in the Blackfoot River drainage, Montana. Bahr and Shrimpton (2004) observed downstream spawning movement by fluvial–adfluvial bull trout in a British Columbia river drainage. Bull trout also exhibit downstream migrations out of lakes to spawning areas in outlet streams (i.e., allacustrine migrations; Thomas 1992; Herman 1997; Northcote 1997; Kelly-Ringel and DeLaVergne 2000; Hogen and Scarnecchia 2006). However, none of these populations migrate more than 10 km downstream from the lake's outlet, and all spawn directly in the outlet stream or less than 8 km up a side tributary.

Many recovery or restoration plans describe passage barriers as a significant risk to the long-term persistence of bull trout (USFWS 2002). These plans

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typically direct future work at restoring passage to spawning areas that occur upstream of adult habitats but tend to provide less emphasis on areas used in downstream migrations. This is especially the case for lake-dwelling bull trout. In fact, most major lakes in the U.S. bull trout recovery area have dams at or near their outlets, and many of these dams lack fish passage facilities (USFWS 2002). Extensive work has been undertaken to identify and remove upstream passage barriers to restore or expand these lacustrine–adfluvial populations (USFWS 2002). Unfortunately, less attention has been given to outlet spawning or allacustrine populations from these lakes. Spawning and juvenile rearing habitat downstream of these lakes is often abundant; however, fish with allacustrine spawning life cycles have probably been lost, as most of these dams have been in existence for 30 or more years.

We examined a unique allacustrine migrational pattern in bull trout within the Pend Oreille River system of northern Idaho and found it to be more extensive than previously documented for bull trout populations. Understanding the different migratory life cycles that bull trout may exhibit could increase our ability to improve or expand their populations beyond our current expectations. Expansion of bull trout populations may include identifying passage barriers in downstream migration pathways.

Study Area

This study was conducted in the Pend Oreille River basin (Figure 1). The Pend Oreille River begins at the outlet of Lake Pend Oreille and flows 189 river kilometers (rkm) through northern Idaho, Washington, and southern British Columbia to its confluence with the Columbia River near the border of the USA and Canada. The study area was confined upstream of Albeni Falls Dam (operated by the U.S. Army Corps of Engineers), which blocks upstream movement of fish in the Pend Oreille River. Albeni Falls Dam is located about 5 rkm upstream of the Idaho–Washington border and 7 rkm downstream of the confluence of the Priest River. Lake Pend Oreille is located about 36 rkm upstream from the mouth of Priest River. Albeni Falls Dam controls the flow in the Pend Oreille River and water elevations in Lake Pend Oreille. The mean annual discharge at Albeni Falls Dam at the U.S. Geological Survey gauge below Albeni Falls Dam is 697 m^3/s (peak discharge = 3,913 m^3/s) over the period of record (1960–2004). When bull trout utilize the Pend Oreille River (September–June), water velocities greater than 1.0 m/s are common during spring runoff, whereas fall and winter velocities are typically around 0.2 m/s.

The majority of bull trout spawning within the drainage occurs in tributaries to Lake Pend Oreille (PBTTAT 1998); however, spawning is also known to occur in tributaries of the Priest River. Upstream fish passage in the Priest River basin is blocked by a dam at the outlet of Priest Lake, 71 rkm upstream from its mouth. Within the Priest River (downstream of Priest Lake) the only known spawning occurs in the East River watershed, which enters Priest River 34 rkm from its mouth. The majority of spawning within the East River watershed occurs in the Middle Fork East River.

The Middle Fork East River is a third-order tributary with a watershed of about 8,750 ha. The river is about 6–8 m wide near the mouth and about 3 m wide near the upstream limits of bull trout distribution. The river also supports westslope cutthroat trout *O. clarkii lewisi*, brook trout *Salvelinus fontinalis*, and brown trout *Salmo trutta*. The stream gradient ranges from 2% to 5%. The majority of this watershed is timbered, and clearings occur because of fires, logging, and rock outcrops. The watershed has been managed intensively for timber for nearly a century.

Methods

Six adult bull trout were captured by electrofishing in the Middle Fork East River from August 14 to 16, 2002 (Figure 1). These adults had a mean total length of 590 mm (range = 450–732 mm; Table 1). Bull trout were surgically implanted with transmitters (Lotek Engineering, Newmarket, Ontario; Model MBFT-5; weight = 8.9 g in air, $< 1\%$ of fish body weight in air; weight = 4.3 g in water; expected life = 294 d) using methods similar to Ross and Kleiner (1982). After surgery, bull trout were released at the site of capture.

Fixed-station and mobile tracking was used to monitor fish movements. The fixed stations were placed in areas that we believed would help evaluate (1) movement of radio-tagged bull trout to and from different drainages or suspected overwinter areas and (2) whether entrainment over Albeni Falls Dam was a significant source of mortality. Seven radio receiving stations were installed in October 2002: four were located at Albeni Falls Dam, one was located at the mouth of the Priest River, and two were located on the railroad bridge at Dover, Idaho (about 26 rkm upstream of the Priest River; Figure 1). Each station was equipped with an SRX-400 radio receiver connected to aerial Yagi antennas. The receivers were supplied with either AC or DC power; solar panels were used to recharge DC power systems. At all locations, a beacon tag was used to monitor receiver status. The beacon tag was programmed to transmit a signal for 1 min of every hour. Each system was calibrated using a transmitter deployed at various distances from the receiving stations. Complete coverage of the river's width was

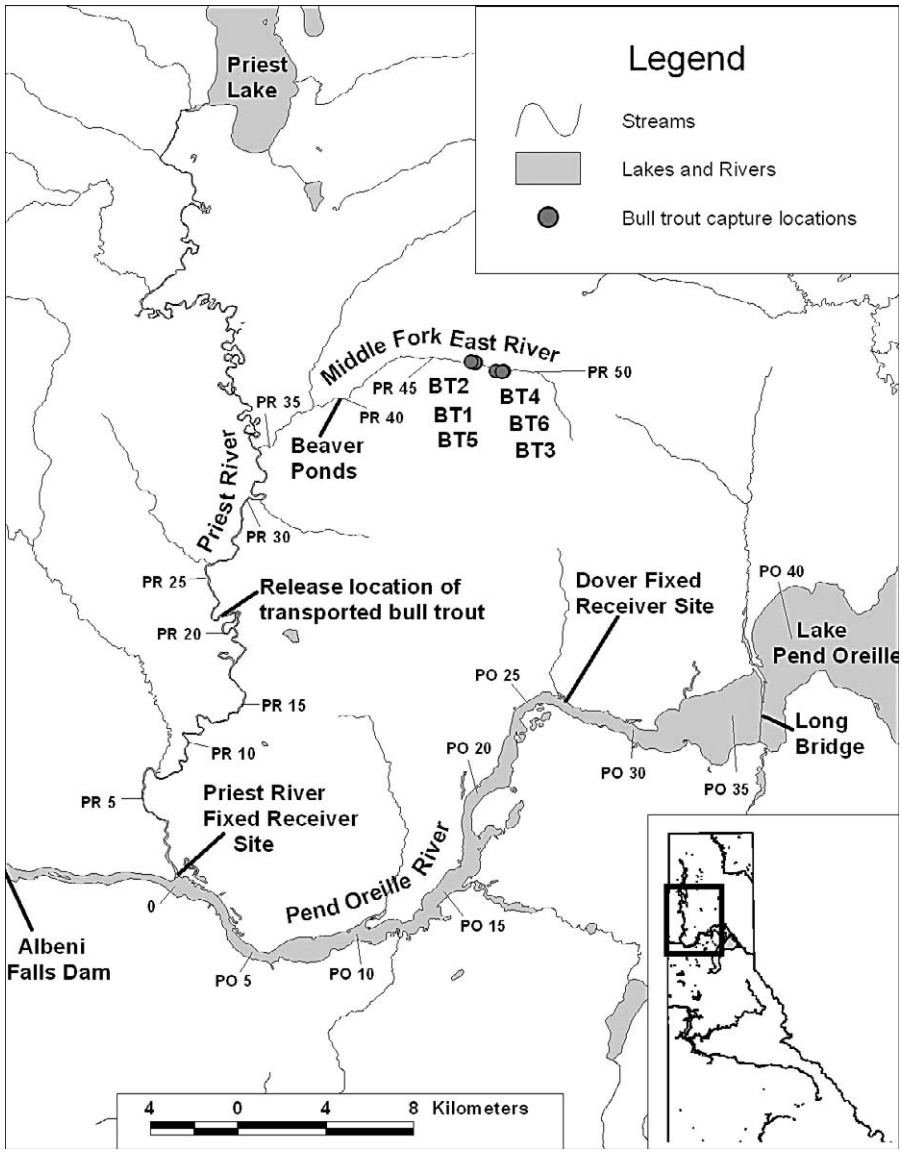

FIGURE 1.—Radio-tagging locations for six bull trout (BT1–BT6) in the Middle Fork East River, Idaho, and the portion of the watershed in which subsequent spawning and overwintering areas were examined. Two fixed-receiver stations are shown, and river kilometers (rkm) are marked in 5-km increments upstream from the confluence (rkm 0) of the Priest (PR) and Pend Oreille (PO) rivers.

achieved at the Dover and Priest River sites; with the exception of a narrow and deep trench near the forebay of Albeni Falls Dam, the river width at the dam forebay was also covered. In this area, water depths exceeded 15 m and would have attenuated signals transmitted from implanted bull trout. All fixed receivers were inspected and data was downloaded approximately once every 2 weeks from October 2002 to September 2003. Data were backed up on a laptop computer, and a hard copy record was made of the start and end times of receiver operation. At the time of each inspection, the power system was inspected and repaired if necessary. The beacon tag was also checked for proper operation. Data processing consisted of reviewing each download file for active tags and beacon tag signals. Data summaries were prepared and used to help locate fish during mobile tracking efforts.

In addition to the fixed stations, movements of

TABLE 1.—Biological and location data for six bull trout that were radio-tagged in the Middle Fork East River (MFER), Idaho, in August 2002 and tracked until September 2003. Overwintering areas were Lake Pend Oreille (LPO) and the Pend Oreille River (PO) near the Priest River (PR) confluence.

Fish number	Total length (mm)	Sex	Approximate date in 2002		Overwinter location	Repeat spawner?	Number of locations
			Spawning	Migration from MFER			
BT1	590	♀	Sep 5	Sep 19	LPO near Long Bridge	Yes	20
BT2	550	♀	Sep 5	Sep 19	LPO about 1 km upstream of Long Bridge	Unknown	15
BT3	497	♂	Sep 19	Dec 9[a]	LPO	No	21
BT4	722	♀	Sep 11	Dec 9[a]	LPO	Yes	30
BT5	732	♀	Sep 11	Dec 9[a]	PO just upstream from PR	Yes	26
BT6	450	♀	Sep 19	Dec 9[a]	PO about 5 km upstream from PR	Unknown	28

[a] These fish were trapped and transported to PR on this date.

tagged bull trout were monitored using SRX-400 radio receivers operated from fixed-wing aircraft and via foot, raft, and truck. Ground surveys were conducted approximately weekly from August to December 2002; once on March 23, 2003; and then weekly from July to September 2003. Five aerial surveys of the Pend Oreille River were conducted on December 30, 2002, and January 2, February 4, July 7, and September 12, 2003. Flights traveled along the Pend Oreille River from Albeni Falls Dam upstream to Lake Pend Oreille and up the Priest River. Multiple passes were used to reduce the chance that tags would be missed. Any fish detected during the mobile surveys were noted on a map, and if possible a Global Positioning System (GPS) unit was used to record the latitude and longitude of the fish location. When the GPS unit could not communicate with a sufficient number of satellites (due to heavy forest cover), locations were marked on a U.S. Geological Survey topographic map (1:24,000 scale). The speed of the aircraft reduced the accuracy of the GPS positions. Due to signal attenuation, relocations could not be made when fish were within deep (>15 m) parts of Lake Pend Oreille or the Pend Oreille River.

Radiotelemetry data were analyzed by noting the distance each fish traveled between surveys. Positions were plotted on a map. Stream kilometers were determined from the map to measure distance traveled. Data were separated into prespawning (before September 5, 2002), spawning (September 5, 2002 to initiation of movement from known spawning areas), postspawning (movement from known spawning areas to December 15, 2002), overwintering (December 15, 2002, to May 20, 2003), and repeat spawning (after May 20, 2003) periods.

Results

During the first month (August 15–September 19, 2002) of the study, all six bull trout remained in the Middle Fork East River and moved less than 200 m from their capture locations (Table 2). The first spawning activity was observed on September 5, 2002; by September 19, all six fish exhibited some type of spawning behavior (paired with other bull trout, constructing a redd, or located near a redd; Table 1).

Within 14 d of spawning, two fish (BT1 and BT2) moved downstream about 12 km into the Priest River (Figure 2). A later survey (November 13, 2002) relocated both of these bull trout in Lake Pend Oreille just upstream of the Long Bridge, where they generally remained throughout the winter (Figures 1, 2). Migrations to Lake Pend Oreille occurred before the Dover and Priest River fixed telemetry sites became operational on October 10, 2002.

The remaining four bull trout (BT3–BT6) migrated more slowly down the Middle Fork East River after spawning. All four radio-tagged bull trout eventually moved into a shallow (<1.5 m deep) pond complex (constructed by American beavers *Castor canadensis*) between October 3 and November 15, 2002, and remained there until December (Figures 1, 2). During the period of beaver pond use, we identified at least

TABLE 2.—Distance moved by six radio-tagged bull trout in the Middle Fork East River, Idaho, during prespawn, spawning, postspawn, and overwinter periods, as determined from radiotelemetry tracking in 2002 and 2003. Under postspawn, numbers in parentheses indicate how many kilometers the fish moved upstream. During postspawn movements, BT3–BT6 were transported for about 17 km to avoid stranding in low water.

Fish number	Distance moved (km)			
	Prespawn	Spawning	Postspawn	Overwinter
BT1	0.17	0.05	85.81 (36.30)	4.65
BT2	0.18	0.03	83.66 (36.30)	1.02
BT3	0.06	0.05	>87 (36.30)	Unknown
BT4	0.00	0.01	>86 (36.30)	Unknown
BT5	0.10	0.06	48.52 (0.79)	0.68
BT6	0.00	0.04	53.87 (5.51)	1.27

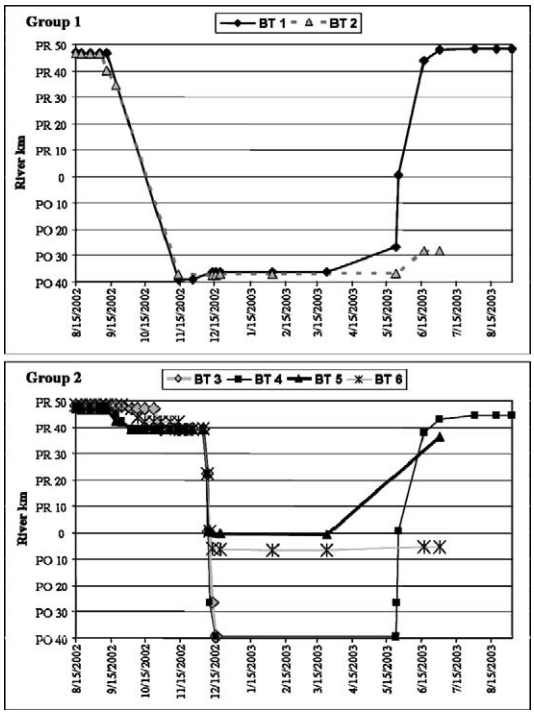

FIGURE 2.—Distances moved in 2002 and 2003 for six bull trout (BT1–BT6) that were radio-tagged in the East River watershed, Idaho. Group 1 (BT1–BT2) migrated from spawning tributaries shortly after spawning; group 2 (BT3–BT6) made postspawning movements to a beaver pond complex and, due to low-water stranding, were captured there and released 17 rkm downstream on December 9, 2002. Distances are denoted in 10-rkm increments from the confluence (rkm 0) of the Priest (PR) and Pend Oreille (PO) rivers; measurement begins at the tagging site. The East River enters Priest River at PR 34; the transported bull trout were released at PR 22; and Lake Pend Oreille encompasses PO 36–40.

eight other adult bull trout that had died in or near this area. In an effort to reduce study fish mortality, we captured, transported, and released the radio-tagged bull trout into the Priest River 17 rkm downstream (22 km from the mouth) on December 9, 2002. Three other adult bull trout were also captured from beaver ponds during this effort. All the captured bull trout appeared emaciated (ribs showing, loose skin, and thin bodies).

After release, the four radio-tagged bull trout quickly migrated either to Lake Pend Oreille or to the Pend Oreille River. It took between 12 and 40 h for all four fish to pass the fixed station at the mouth of Priest River (22-km migration). Two of the bull trout moved upstream past the fixed receiver site at Dover (52-km migration) within 4 d of release into the Priest River and presumably continued the short distance (10 km) upstream into Lake Pend Oreille (Figure 2). These two bull trout were not relocated during the winter because the deep nature of Lake Pend Oreille made their detection difficult. The other two bull trout migrated less than 8 km up the Pend Oreille River to overwintering locations (Table 1; Figure 2). None of the bull trout that we were able to locate during winter moved more than 5 km (Table 2; Figure 2).

After winter, three of the bull trout moved back into the East River watershed (Table 1; Figure 2). All these fish made downstream movements within the Pend Oreille River to enter the Priest River and eventually swam 34 km upstream into the East River. Two of these bull trout emigrated downstream from Lake Pend Oreille to Priest River at travel rates of 1.73 and 0.54 km/h. Both were relocated on June 17 in either the East River or the Middle Fork East River, and both migrated steadily upstream within the Middle Fork East River to known bull trout spawning areas. The final locations documented in September 2003 were within 1.3 and 3.5 km of the locations in September 2002. The third bull trout that returned to the East River overwintered in the Pend Oreille River (Table 1; Figure 2). It was located in the East River on July 1, 2003. We were unable to detect this fish after this date, probably because of battery expiration.

The transmitters on the two other bull trout that had been tracked throughout the winter probably expired shortly after July 1, 2003. Both were in the Pend Oreille River at that time. We could not ascertain whether these fish were alive or dead or had expelled their transmitters.

Discussion

Of the six adult bull trout monitored between August 2002 and September 2003, four exhibited a definite allacustrine life history, using Lake Pend Oreille to overwinter. The other two used the Pend Oreille River to overwinter (i.e., a fluvial–adfluvial life history). Either way, the Middle Fork East River bull trout population appears to migrate upstream into the Pend Oreille system to complete a portion of its life history.

After spawning, all fish exhibited a downstream migration from the Middle Fork East River into the Pend Oreille River. None of the fish attempted to migrate upstream towards Priest Lake, and we found no fish in the Pend Oreille River downstream of its confluence with the Priest River. All six fish migrated at least 48 km from spawning sites to reach overwintering locations, and the total upstream movements ranged from 0.79 to 36.3 km. The four fish that migrated to Lake Pend Oreille migrated over 80 km from spawning sites to overwintering areas; more than 36 km of their migration was upstream. Similarly,

postspawn bull trout in the Wenaha River, northeast Oregon, migrated downstream to the Grand Ronde River and then moved both upstream and downstream to overwintering areas (Hemmingsen et al. 2001, 2002).

Bull trout that spawn in the Middle Fork East River migrated 36 km down the Pend Oreille River and then swam 34 km up the Priest River before they enter the East River watershed. Other bull trout populations are known to have an allacustrine spawning life cycle (Thomas 1992; Herman 1997; Kelly-Ringel and DeLaVergne 2000; USFWS 2002; Hogen and Scarnecchia 2006). However, none of these populations is believed to migrate more than 10 km downstream from the lake's outlet, and all spawn directly in the outlet stream or less than 8 km up a side tributary. Juvenile bull trout from the Middle Fork East River must make this migration in reverse to reach Lake Pend Oreille without the benefit of having made this journey before. Chemicals or pheromones given off from other bull trout in Lake Pend Oreille may signal the juvenile bull trout to turn upstream toward the lake, similar to observations of sea lampreys *Petromyzon marinus* (Teeter 1980) and salmon (White 1934; Nordeng 1971, 1977; Solomon 1973; Sutterlin et al. 1982; Quinn et al. 1983; Stabell 1984; Quinn and Busack 1985; Quinn and Tolson 1986; Groot et al. 1986).

We recognize that this study's small sample size ($N = 6$) makes it difficult to draw definitive conclusions about the bull trout population that spawns in the Middle Fork East River. For example, we cannot estimate the typical timing of their migration or the percentage of the population that overwinters in Lake Pend Oreille versus the Pend Oreille River. However, all six bull trout we studied displayed a postspawning migration that included downstream movements within the Priest River system followed by upstream movements within the Pend Oreille River to reach overwintering grounds. This common behavior illustrates how bull trout can have extensive and complex downstream migrations from rivers and lakes to reach spawning habitat.

We also recognize that capturing and moving the four bull trout from the beaver ponds may have altered the results, especially considering our limited sample size. However, if the fish had not been moved, they would have all died and little would have been learned from this study. We did not simply release fish below the beaver dam complex because unusually low flow conditions existed at that time and might have prevented fish passage to the Priest River. To maximize survival of the implanted bull trout without compromising the study, we moved them to the closest place on the Priest River accessible by truck, representing a downstream movement of 17 km. We believe this movement did not compromise the study and was not counter to the fish's intended direction, because upon release they immediately moved downstream into the Pend Oreille River and then turned upstream toward Lake Pend Oreille. This is the same movement pattern displayed by the two radio-tagged fish that were not transported.

The blocking or delay of downstream bull trout migrations by beaver ponds is not an unusual finding. During redd count surveys in northern Idaho, adult migratory bull trout (sometimes > 30 fish) are commonly observed milling about in beaver ponds after spawning (J.M.D., personal observation). What does seem unusual is the duration of fish stranding in the beaver pond (nearly 2 months before being transported). This atypical behavior is probably due to unusually low precipitation during fall 2002. Typically, in northern Idaho, fall rains occur in October and November, discharge increases, and large volumes of surface flow spill over beaver dams. Such flows did not occur in 2002 until late December.

This work demonstrates the need for new approaches to expanding bull trout populations into historically occupied habitats. Eliminating barriers downstream of lakes could potentially enhance bull trout populations considerably. Bull trout from the Middle Fork East River made downstream migrations of over 36 km before turning upstream to spawning locations. Historical and ethnographic reports also suggest that before Albeni Falls Dam was constructed, bull trout migrated even further down the Pend Oreille River from Lake Pend Oreille to reach spawning locations (Gilbert and Evermann 1894; A. Smith, unpublished 1936 manuscript on Kalispel ethnography, *Kalispel Tribe of Indians v. United States,* Indian Claims, Docket 94). Tributaries situated 50 km or more downstream from lakes should receive greater consideration in bull trout recovery plans.

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